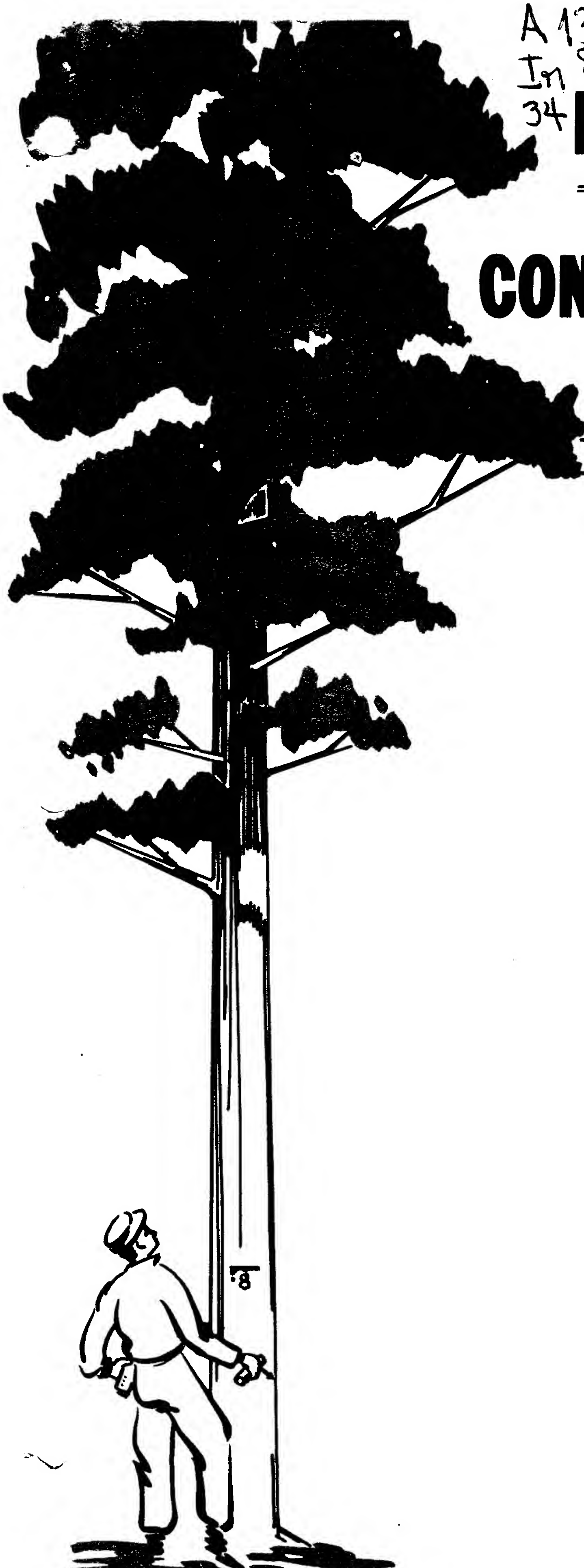


FOREST CONTROL by CONTINUOUS INVENTORY

"---you shall not muzzle an ox when it is
treading out the grain."
First Corinthians 9:9

Milwaukee, Wis. January, 1957 No. 34

One impulse from a vernal wood
May teach you more of man,
Of moral evil and of good
Than all the sages can

WORDSWORTH

The Forester

THE MORE WE FLAIL AND FLOUNDER

THE MORE WE FOUNDER AND FAIL

Time is life's most priceless condiment. To consume time wisely; that is the thing; and you may be sure long range planning will help.

I have been cruising timber for many years, one way or another, and this I have found out -- as crude forest management methods and growing populations reduce our timber supply, so will these factors also increase the intensity of management of the remnant forests. Time does these things. Ordinary mankind just tags along.

But the wise ones will not wait for timber "dregs" to cut and forest remnants to manage. Instead, they will bring their lights to bear in such wise that the problem will be seen before it comes, and the solution planned far, far in advance. Long before intensive management of the forest is accomplished, vigorous policies must be set up to that end. The first step is knowing the volume and growth of the forest.

"Knowing the growth - knowing the volume - these are not everything," very wise foresters tell us. Of course not, but they are fundamental things, and 50 years of forestry have not given us these answers for large forest properties - nor a common sense method of finding the answers. When we have any answers at all, they are old, stale and incomplete. They are seldom representative of the current condition of the whole forest area. In more than 35 years of dirt forestry, I have not seen two successive estimates of timber on the same large forest that could be compared. Not one case can I name. <u>There are none because successive estimates of timber have not been made by comparable methods.</u>

Growth and volume inventories are by no means everything, but they are the first things we need, and they are something we can get from frequently repeated measurements of the many thousands of permanent plots set out by industry during the past 10 years. We need first things first. C.F.I. gives them to us, and every successive measurement will give us more trustworthy growth and mortality answers than the preceding ones.

The platted record of these repeated, comparable measurements establishes the current position and the indicated trend of the capital stocks in the whole forest. It gives the investment value of the forest property and thus indirectly measures the state of being of the dependent timber business. All this results from long-range planning. This is a wise use of time.

CAL STOTT, Forester
U. S. Forest Service, R-9
Milwaukee, Wisconsin

THE STATISTICAL CHECK SHEET

Statistical analysis is a useful tool to the forester. It can be used both forward and backward to make possible accurate estimates with a minimum amount of work. Because many foresters may not wish to dig deeply into mathematics to understand statistics, yet may wish to use statistics, the STATISTICAL CHECK SHEET has been developed. With this sheet and another giving a simple statistical way to determine the number of plots necessary to make a sampling cruise, the forester may control his cruising.

One sheet augments the other. In the first place, the forester would follow out the instructions on the sheet describing HOW TO DETERMINE THE NUMBER OF SAMPLE PLOTS and make a survey based on the number of plots indicated--keeping separate records for each plot. Having done this, he would analyze the results of his cruise on the STATISTICAL CHECK SHEET to find out how well he came out from a statistical standpoint. At the same time he will have developed the information necessary to control the accuracy of surveys in this type of stand.

EXAMPLE

Suppose we have made a sampling survey and now have the following list of individual plot totals for a number of samples set up from the HOW TO DETERMINE THE NUMBER OF SAMPLE PLOTS sheet. (Page 2)

524.637
Oxford

HOW TO DETERMINE THE NUMBER OF SAMPLE PLOTS NEEDED TO MAKE A TOTAL VOLUME ESTIMATE TO A PREDETERMINED DEGREE OF STATISTICAL ACCURACY 1/

There are but two cases--(1) for large tracts, and (2) for small tracts. The first is found by a simple calculation. The second is determined from the first by a simple correction based on the tract acreage and plot size.

Suppose a total volume estimate, statistically accurate within 10% is desired for a mixed sawtimber stand of good density and average uniformity.

---

(1) For a large tract (1000 acres or more) (see tables for F and M below)

No. of plots (N) = Stand Factor (F) x Statistical Accuracy Multiplier (M)

EXAMPLE: N = stand factor 2 x statistical accuracy multiplier 20

or N = 40 plots.

---

(2) For a small tract (for the example let's use 50 acres) a few less plots are required. First determine the number of plots for a large tract as shown above; then divide this number by:

$$1 + \frac{\text{Number of plots for a large tract (N) x Plot size (a)}}{\text{Acreage of small tract (A)}}$$

EXAMPLE: $\frac{(N) \times (a)}{(A)} = \frac{(40) \times (0.2)}{(50)} = \frac{8}{50}$, or 0.16

No. of plots for small tract = $\frac{\text{40 plots for large tract}}{1.16}$, or 34 plots.

TABLE OF STAND FACTORS (F) 2/ (1/5 acre plots)

SIZE CLASS OF TIMBER	Predominant dbh classes	GOOD DENSITY Uniform	GOOD DENSITY Average	MEDIUM DENSITY Uniform	MEDIUM DENSITY Average	MEDIUM DENSITY Patchy	POOR DENSITY Uniform	POOR DENSITY Average	POOR DENSITY Patchy
Large sawtimber	16"+	3	5	7	10	20	15	20	40
(F) Mixed sawtimber		1	2	3	5	10	10	15	30
Small sawtimber	10"-14"	1	1	2	4	10	7	10	20
Mixed small sawtimber -cordwood		1	2	3	4	10	7	10	20
Cordwood	6"-8"	1	1	2	3	7	7	10	20

LIST OF STATISTICAL ACCURACY MULTIPLIERS (M)

	Degree of accuracy (E)	Multiplier (M)	Degree of accuracy (E)	Multiplier (M)
	5%	80	20%	5
(M)	10%	20	25%	3
	15%	9	31%	2

1/ Method is derived from original work done about 1938 at the Lake States Forest Experiment Station, St. Paul, Minnesota, by silviculturists S. R. Gevorkiantz and William A. Duerr. Risk of error exceeding limit E selected in Table M is 1 to 21. Statistical accuracy multipliers (M) are equal to 1 / (5 times the square of E).

2/ Stand factors (F) equal (20) x (coefficient of variation)^2. See page following this sheet for guides to stand density and uniformity.

JUDGING DENSITY

(1) The number of trees 6" dbh and larger per acre is a good guide to density. The table below shows the ranges considered to represent medium density in different timber size classes.

Timber Size Class	Number of Trees per acre	Suggested Sample Plot Size (acres)		Suggested Sample Plot Radius (feet)
Large sawtimber (16" + dbh)	35-50	1/3	(0.333)	67.984
Mixed sawtimber	40-65	1/4	(0.250)	58.876
Small sawtimber (10"-14" dbh)	55-95	1/5	(0.200)	52.660
Mixed small sawtimber-cordwood	80-140	1/7	(0.143)	44.506
Cordwood (6"-8")dbh)	130-225	1/10	(0.100	37.236

(2) Another method of judging density is use of the hardwood percent of stocking formula. Considering 50%-80% as medium density gives results almost identical with the table above. Include trees 6" dbh and larger.

$$\text{Percent of stocking} = \text{No. trees per acre} \times \frac{\text{Average dbh} - 4}{10}$$

JUDGING UNIFORMITY

The appearance of the stand is the only guide to uniformity. Average uniformity allows 20-40% of the stand in patches of different size classes or density than that judged to represent the stand as a whole. Stands with less than this variation are considered uniform. Stands with many openings and those about half way between size class or density classifications are about the only ones that fall into the patchy group.

PLANNING PLOT LAYOUT

Regularly spaced plots located by distance (steel tape preferred) and bearing (pocket compass) are sufficiently random to satisfy statistics and at the same time the requirements of ordinary cruising.

After the number of plots has been determined, the spacing between plots to cover the area regularly may be determined quickly:

1) Multiply the number of acres in the tract by 10 to get square chains (50 acres x 10 = 500 sq. chs.).

2) Divide by the number of plots ($500 \div 34 = 14.7$)

3) a. Take the square root of this number to find approximate square spacing ($\sqrt{14.7} = 3.8$, or about 4 chains each way), or

   b. Find two numbers which multiplied together will approximately equal this number for rectangular spacing (14.7 = approx. 3 x 5 chains).

Using these figures to the nearest chain, starting anywhere on or off the tract, draw lines on a base map to make a grid over the area to be cruised. Locate plots at the line intersections; or, if you desire, stagger plots on every other line to give triangular location. There is no assurance that one method will give results superior to the other. Add or subtract a plot wherever you choose to secure the proper number of plots.

In the field, locate plots by bearing and distance from points recognized on the map. Such points are section corners, road intersections, school houses, bridges, and other physical features. Generally it is advisable to run all lines on cardinal directions and not try to parallel section lines. Let plot centers fall where they may by bearing and distance; do not arbitrarily move plot centers from where they fall.

Do careful work on each plot and accurate results within limits set up should ensue.

U. S. DEPARTMENT OF AGRICULTURE - Forest Service, Region 9, Milwaukee, Wis. May, 1949
(slightly revised, Region 7, Upper Darby, Pa., December, 1956)

<u>Table I</u>

SAMPLE PLOT RECORDS

(Board feet per acre on <u>each</u> plot)

13279	2110	14153	7021	310
5426	13975	11950	4915	9925
11310	9000	(210)	13241	13100
2131	15301	12595	4768	18239
12123	7234	(22950)	6125	12100
22003	5864	10921	16121	13250
18800	9365	11940	14910	10450
10100	3110	4321	12152	13215
12916	11210	17635	10892	12841

Total of all samples	-	485,507
Number of sample plots	--	45
Average sample or <u>Mean</u>	-	10,789 1/
Range of samples	-	210 to 22,950
Group range chosen	-	1,000
Number of groups	-	23

1/ This is the strongest figure of the survey. An "assumed" and a corrected "arithmetic" average are used on the STATISTICAL CHECK SHEET <u>only for the purposes of making the statistical analysis.</u> In a final report, the ± limit of error should be referenced to the actual average sample.

HOW TO LIST THE SAMPLE PLOT INFORMATION

First divide the full range of record into even width groups. Usually the group width used is between 1/15 and 1/25 of the range from 0 to the highest number. If we divide the range (22950 - 210 =) 22,740 by 20, we find our groups would have a width of 1,137. Easier to use would be a group width of 1,000 which gives us 23 groups. Beginning with 0 the limits of the groups are listed in column 1 on the STATISTICAL CHECK SHEET. (Page 6).

In column 2, the number of records falling in each group is tallied by dot-dash (⊠ etc.), or vertical lines with horizontal cross (卌 卌 etc.). In column 4, this information is relisted as a number. Columns 1 and 2 are on the form just to make the listing from field notes easy. Once the information is transferred to column 4, columns 1 and 2 are not used further.

SETTING UP THE SHEET

The next step is to determine the MEAN (the average) of all the samples. This is done by adding up all the sample records and dividing this sum by the total number of records. This mean will fall within the limits of one group. In column 3, mark an X beside this group number. On this line, enter the figure 0 in columns 5, 6, 7 and 8. In our example, group No. 10 is the average and the 0's appear on that line.

Above the 0 in column 5 list -1, -2, -3, etc. Below the 0, list 1, 2, 3, etc. On respective lines in column 7, list the squares of the numbers just listed in column 5. In all cases, the square is a positive number.

FIRST CALCULATIONS

Across on each line, multiply the figure in column 4 by the figure in column 5 and list the product in column 6. Similarly multiply the figure in column 4 by the number in column 7 and list the product in column 8. Total columns 4, 6, and 8. We now have the information necessary to make a statistical analysis. Total of column 6 may be plus or minus.

BLOCK A - correcting the assumed average

In BLOCK A on the ASSUMED AVERAGE line list the group number checked as the average in column 3 and show three zeros to the right of the decimal point. In the space provided on the next line, enter the total of column 6. Divide this by the total of column 4 and list the quotient opposite the symbol (d). As indicated by the plus or minus sign, add this to or subtract it from the "assumed" average to get the ARITHMETIC AVERAGE (M). This concludes Block A.

VIRGIN TIMBER

STATISTICAL CHECK SHEET

NORTHERN HARDWOOD - HEMLOCK   45 1/5 ACRE PLOTS

GROUP-RANGE (1)	(f) tally (2)	GROUP No. (3)	(f) No. (4)	$(\bar{x})$ (5)	$f\ (\bar{x})$ (6)	$(\bar{x})^2$ (7)	$f\ (\bar{x})^2$ (8)
0 – 999	..	0	2	-10	-20	100	200
1000 – 1999		1					
2000 – 2999	..	2	2	-8	-16	64	128
3000 – 3999	.	3	1	-7	-7	49	49
4000 – 4999	:.	4	3	-6	-18	36	108
5000 – 5999	..	5	2	-5	-10	25	50
6000 – 6999	.	6	1	-4	-4	16	16
7000 – 7999	..	7	2	-3	-6	9	18
8000 – 8999		8					
9000 – 9999	:.	9	3	-1	-3	1	3
10000 – 10999	::	10	4	0	0	0	0
11000 – 11999	::	11	4	1	4	1	4
12000 – 12999	Г:	12	6	2	12	4	24
13000 – 13999	Г:	13	6	3	18	9	54
14000 – 14999	..	14	2	4	8	16	32
15000 – 15999	.	15	1	5	5	25	25
16000 – 16999	.	16	1	6	6	36	36
17000 – 17999	.	17	1	7	7	49	49
18000 – 18999	..	18	2	8	16	64	128
19000 – 19999		19					
20000 – 20999		20					
21000 – 21999		21					
22000 – 22999	..	22	2	12	24	144	288
–							
–							
		N	45	$\sum f\bar{x}$	+16	$\sum f\bar{x}^2$	1212

×

σ = standard deviation

c = coefficient of variation

e = percent of standard error (as a decimal)

f = frequency of occurrence

N = total number of records

$\bar{x}$ = deviation from assumed average group number (A)

(block A)

Assumed Average 10.000 (A)

$$\frac{\sum f(\bar{x})}{N} = \frac{+16}{45} = +0.356 \quad \text{(d)}$$

Arithmetic Average 10.356 (M)

(block B)

$$s^2 = \frac{\sum f(\bar{x})^2}{N} = \frac{1212}{45} = 26.933333$$

$$\boxed{\sigma^2 = s^2 - d^2}$$

$$-d^2 = 0.126736$$

$$\sigma^2 = 26.806597^*$$

$$M^2 = 107.246736$$

$$c^2 = 0.249953$$

$$N = 45$$

$$e^2 = 0.005555$$

e = 0.075 probability 0.6745 (1σ)

$2e$ = 0.150 OR ± 15.0% probability 0.9545 (2σ)

$3e$ = 0.225 probability 0.9973 (3σ)

* When $N < 30$, multiply σ^2 by $\frac{N}{N-1}$, before proceeding with division by M^2

USDA SCS MILWAUKEE WIS 1957

BLOCK B - the statistical analysis

STANDARD DEVIATION: - In Block B on the top line as indicated, list the total of column 8. Divide this by the total of column 4 and list the quotient to 6 decimal places on the line to the right.

Square (d) which is found in Block A and subtract this square from the figure calculated above. The remainder will be the square of the standard deviation. 2/

COEFFICIENT OF VARIATION:- Divide the square of the standard deviation by the square of the arithmetic average, (M) from Block A. This quotient, listed to six decimal places at the left of the arrowed equal sign ($\leftleftarrows$) is the square of the coefficient of variation.

STANDARD ERROR OF THE MEAN, (M): - Divide the square of the coefficient of variation, c^2, by the number of plots (total of column 4) and list this quotient to six decimal places at the left of the arrowed equal sign. This figure is the square of the standard error of the mean. By taking the square root of this figure, we get e , the standard error of the mean. This, the figure we have been looking for, represents the control on the accuracy of our cruise. The standard error may sometimes be called the limit of error for a probability of 1 standard deviation.

PROBABILITY

It is "probable" that the means of 67% of similar surveys made in the same stand of timber using the same number of plots (similarly located, but not identical) will fall within this limit above or below the true average volume of the stand cruised. In our example, we would expect two-thirds of a number of similar surveys made in this stand to come within 7.5 percent above or below the true mean (average) for the stand. (This absolutely true mean would be determined by making a 100 percent survey, which is what we are trying to avoid by use of sampling techniques.)

If we multiply e by 2, the probability is that 95 percent of the time the means of similar surveys will be within this 2e limit of error above or below the absolutely true mean. In our example, this would be two times ± 7.5% or ± 15.0%. Thus, to state the same thing in a different way, it is probable that only 1 out of 22 surveys we might make on this same pattern would have an error greater than 2e above or below the true mean. For general use, we usually consider that 21 chances out of 22 (a .9545 probability) that we are within our limit of error is a good risk. We may also say we are working with a limit of error of two standard deviations.

2/ When less than 30 plots are used, divide this remainder by N/N-1 before proceeding to the next step.

ERROR

The error we have been discussing is a limit of error and not the actual error of our survey. For all we know, the mean of our particular cruise may exactly agree with the true mean of the stand. On the other hand, it could be the 1 out of 22 that misses the value of the true mean of the stand by more than $\pm$ 15.0% (but it is very unlikely - one chance in 370 - that it would be more than 22.5%).

In the use of statistics our interest lies principally in the fact that with it we can control our surveys to be most of the time within a chosen limit of error. We shall never know exactly what our error may be; for, if we are sampling, we shall not be making a 100 percent cruise with which to compare the mean of our sample cruise. We usually make one survey and consider it a good enough chance that this is one of the surveys that does fall within the 21 out of 22 chance that we do not exceed the error limit of 2e.

TURN ABOUT

If our survey analysis does not come out with 2e in the range we want it to be, we may take more plots to make it more accurate or we may write our report with a note with respect to the accuracy attained. If our accuracy was low, next time we shall plan to use more plots in this same type of timber. If the accuracy was higher than necessary, we may cut down on the number of plots used next time for similar timber stands. If there is a chance that we may wish to add more plots to the cruise at hand, the statistical analysis should be made as soon as possible in the order of steps in working up our cruise information.

The figures in the TABLE OF STAND FACTORS (F) on the sheet describing HOW TO DETERMINE THE NUMBER OF PLOTS, etc. are equal to 20 times the coefficient of variation squared, c^2, as developed on the STATISTICAL CHECK SHEET. Therefore, if we multiply 0.249953 by 20 we shall find the figure we should have read from this table (F). In this case the figure is 5. If we did not read this figure in the first place, the chances are that we did not classify our timber type correctly with respect to the headings on the table.

SUMMARY STATEMENT

The STATISTICAL CHECK SHEET develops all the figures that are needed in controlling the statistical accuracy of a survey. It enables quick analysis of a sampling survey that has been completed and develops experience figures which make it possible to closely judge the number of plots required for a sampling survey of pre-determined statistical accuracy in types which may be recognized as similar to the one for which the analysis was made. Using the same sheet, it is possible to set the control against the average for a species, or for any other special point upon which a control of accuracy may be desired.

MACHINE CALCULATION OF STATISTICAL CHECK

With machine calculation, there is possible another way to collect information needed to make a statistical analysis. This story is told in the third separate of this series.

William Warren Barton
USDA-Forest Service, Eastern Region
Upper Darby, Pa.
September, 1956

January, 1957

INTENSIVE FORESTRY PAYS

by
John Aughanbaugh
Department of Forestry
Ohio Agricultural Experiment Station

One of eastern Ohio's outstanding farm woods is owned by the L. E. Sanor family hear North Georgetown in Columbiana County. This is Experimental Farmwoods No. 11, one of a series of 30 experimental areas supervised by the Ohio Agricultural Experiment Station. Over 70 years ago the elder Sanor fenced this 20-acre woodlot to exclude livestock. Ever since, Sanor's woods has been carefully managed by father, son, and grandson, and it now is an excellent sugar bush and sawtimber stand.

Economic records kept by the Sanors on their farm woods for the past 26 years are as complete, perhaps, as any in the Buckeye State. That farm forestry can pay is proven by the fact that this woodlot has yielded an annual net return from wood products alone of $10 or more per acre. Maple syrup sales brought an additional $5 profit from each acre yearly. These earnings were due to the Sanors' good methods of cutting, using, and marketing their forest products. Their woodland produces, as it should, its proportionate share of the farm income.

In December, 1946, the Sanors made this tract available to the Ohio Agricultural Experiment Station as an experimental woods. Since then a continuous inventory of 30 one-fifth acre sample plots has given accurately its board foot yield by species, tree diameter, grade and vigor classes. Through sound silvicultural management practices, including annual marking of trees for cutting, there is being built up and perpetuated an optimum stand of high-quality trees of valuable kinds. The Sanors are ideal cooperators in this long-range research project.

Charted data on the reserve volume, cut and growth,portray why this woods operation is a success. Briefly the reasons are:

1. Sanor's Woods contains a select, thrifty growing stock, consisting mainly of sugar maple, beech, elm, basswood, cucumber, tuliptree, red maple, and red oak in that numerical order. Its composition by size classes, from seedlings to sawlog trees, approaches full productivity for an all-aged beech-maple stand. Last year's inventory totalled 7,525 net board feet to the acre. When fully-stocked each acre should support 10,000 board feet on this fairly good site.

   Selective cutting of inferior trees each year to favor those of better form and vigor has steadily improved its stocking, growth rate and value. No cull or "wolf" trees exist there. How different from the ruinous hi-grading so often done in Ohio timber lands!

2. The Sanors have, in general, removed less volume than was added by growth, except in a few instances when moderate overcutting was done to take advantage of high prices. Their program of light and frequent cutting insures a profitable return from the same tract continuously. It is, in other words, managed on a sustained yield basis.

Records show that since 1931 over 120,000 board feet of timber, International Scale, came off this 20-acre woodlot. During the period from 1946 to 1956 the yearly harvest per acre was 293 board feet - well below the net growth of 318 board feet (4.9%). Annual ingrowth of trees to the 12-inch diameter sawlog class averaged 90 board feet to the acre.

Single trees, not always the largest, have been cut selectively with a view both to markets and to future crops. In the large timber class (over 20.9 inches diameter breast-high), none but the most vigorous trees increasing rapidly in value have been retained.

Abundant reproduction fills the openings in Sanor's woods, and natural mortality there is practically nil. The Sanors never hesitate to cut a tree in order to favor another of more potential value. Their continued efforts at stand improvement with opportune utilization of the individual tree, result in larger, more frequent, and more profitable harvest cuts.

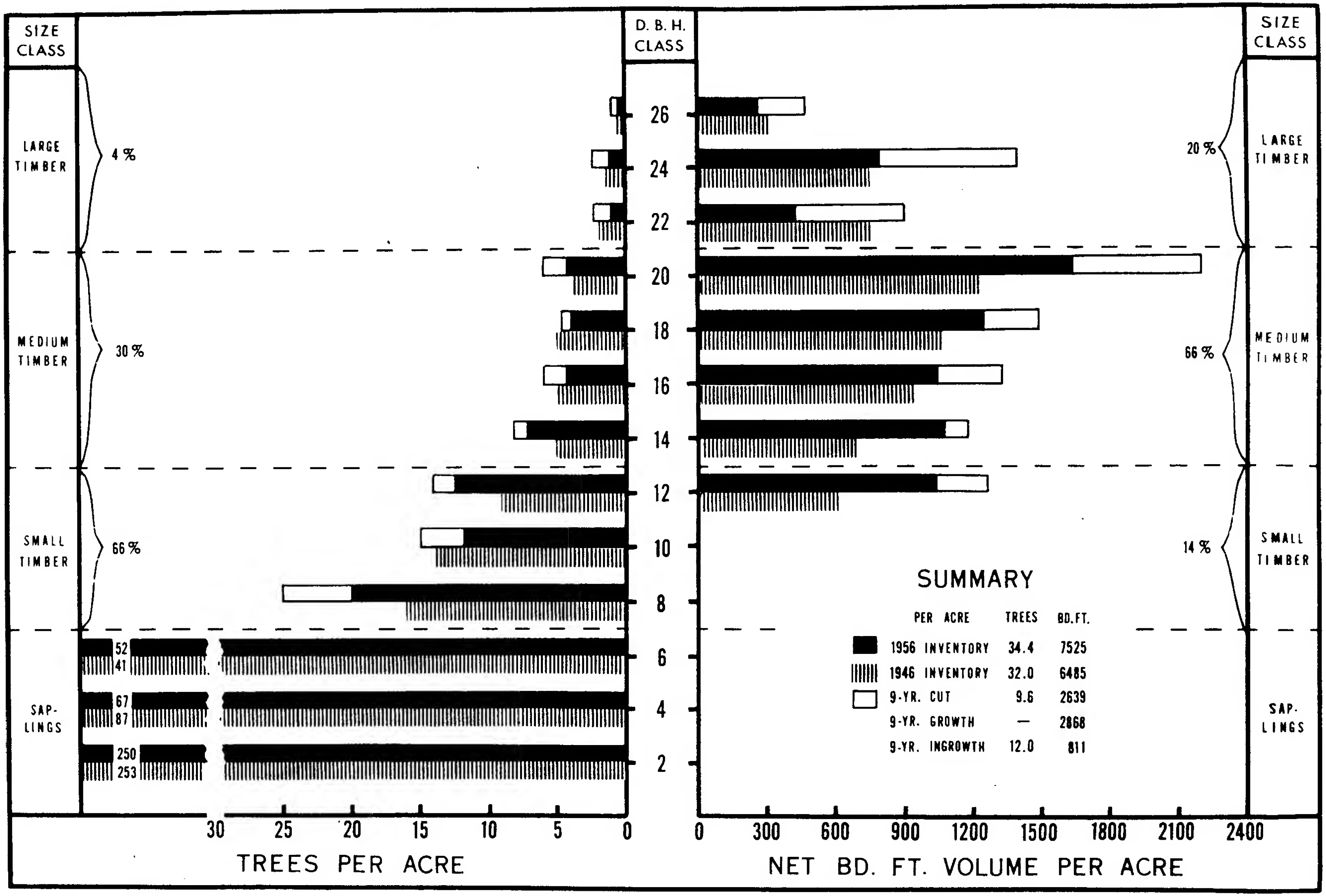
3. These progressive farmers have always done their own woods work, and have practiced close utilization. They have earned more and left their woods in better shape by selling sawlogs instead of stumpage. They thereby market their own labor and that of their team and tractor, as well as their timber. In one year it took 300 man-hours, 60 tractor-hours and 40 horse-hours to harvest 10,000 board feet of logs - a winter cash crop.

They cut each felled tree into the highest quality products possible for which a market is ready or can be found. Their best logs decked by the roadside go to specialty buyers, often for basket veneer. Lower grades of timber supply the farm with building material, fence posts, and fuel wood.

Unutilized tops never clutter the ground in Sanor's Woods. An average of two cords per thousand board feet cut has come from topwood, defective trees and thinnings. It is buzzed into firewood for the two farm homes, the sugaring operation, and for sale locally.

4. Tree appreciation underlies the Sanors' success. They know the trees, their growth habits, their local uses and market value.

Woods work has a challenging appeal to the Sanors, for it is a profitable part of their farm business. They exercise the same energy and foresight in handling their timber crop as for corn, wheat or other field crops. They know that it pays!



GROWING STOCK IN SANOR'S WOODS

WEST TWP; COLUMBIANA CO; OHIO

1946 – 19[illegible]